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# *ARBORICHTHONIUS* N. GEN., AN UNUSUAL ENARTHRONOTE SOIL MITE (ACARINA: ORIBATEI) FROM ONTARIO

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*Abstract.*—***Arborichthonius styosetosus***, n. gen., n. sp., is proposed based on the holotype female collected from soil, St. Lawrence Islands National Park, Ontario. Unusual plesiomorphies include independent tibial and genual solenidia, astegasimy, and a partially divided femur I. Apomorphies include unusual erectile setae and bidactyly.

The suprafamilial group of macropyline oribatid mites forming the Enarthronota (unspecified rank) of Grandjean (1946c), or the synonymous cohort Euarthronota of Balogh and Mahunka (1979), constitutes an assemblage of families of which all but three are usually considered to represent isolated superfamilies. Except for the Brachychthoniidae which is rich in species, most are apparently relicts, represented by one or a few genera each with one or several nominal species. They often exhibit curious mixtures of rather primitive and specialized structures. With regard to certain characters which are quite fixed in the Brachypylina, for example secondary body divisions and leg chaetotaxy, striking diversity is manifest in the Enarthronota.

The purpose of this paper is to describe a new enarthronote mite exhibiting some of the most primitive character states found in the group, and at the same time, specializations not observed in any other oribatid mite taxon. A new genus is proposed, based on this species, but pending the conclusion of ongoing research on enarthronote phylogeny, no familial assignment will be suggested here.

The holotype (deposited in the Canadian National Collection, Ottawa) is an adult female collected from moist soil beneath moss, on Thwartway Island, St. Lawrence Islands National Park, Ontario, Canada, September 1976, by Evert E. Lindquist and Ian M. Smith, whom I thank for allowing me to study it. No other specimens are known, and due to flattening in the original slide mount general body shape and natural dimensions cannot be definitively described. Despite this, its morphological uniqueness justifies the proposals which follow. Morphological terminology used in the description is mostly that developed by F. Grandjean (see Travé and Vachon, 1975 for references).

## *Arborichthonius* Norton, New Genus

Diagnosis.—With character states of the Enarthronota (Grandjean, 1969) qualified as follows. Distinctly astegasime. Subcapitulum anarthric. Body form dichoid, with light sclerotization. 32 pairs of notogastral setae. One secondary "type S" scissure (Grandjean, 1946c) present, bearing erectile setae $e_1$ and $e_2$. Setae $f_1$, $f_2$ erectile, inserted on adjacent intercalary sclerites in pair of circular unsclerotized depressions. No suprapleural band; sclerotization continuous between dorsal and lateral regions. Peranal segment absent. Epimera I with one pair of setae. Palp five segmented. Famulus with bract. Solenidial formula unique (see below). Solenidial coupling variously expressed: absent (seta *d* present) on genua I–III; present (imperfect) on genu IV: absent (*d* present) on tibia III; hyperperfect (*d* absent) on tibiae I and II. Femur I incompletely divided into basi- and telofemur. Ambulacrum with symmetrical bidactyly. Adoral seta $or_2$ enlarged, flattened; $or_1$ minute. No genital tracheae or eyes.

Type species.—*Arborichthonius styosetosus*, n. sp.

## *Arborichthonius styosetosus* Norton, New Species

Etymology.—The Latin generic prefix *arbori* (meaning tree) and Greek trivial prefix *styo* (meaning to erect or stiffen) both refer to the dendriform erectile setae, $f_1$ and $f_2$.

General.—Approximate length of body, not including gnathosoma 245 μm (an estimate due to slightly crushed specimen). Integument, except as noted, lightly but distinctly sclerotized, light yellowish tan in color, finely and irregularly punctate. Unsclerotized arthrodial integument of subcapitulum, legs, and palp distinctly granulate (probable due to localized cerotegument); that of ventral and lateral regions weakly striate.

Prodorsum (Fig. 1).—Lateral regions of prodorsum unsclerotized. Aspis broader than long; posterior margin bends sharply ventrad before joining hysterosomal integument. Rostral tectum very narrow, hardly developed; anterior margin rounded, entire. Bothridial opening flush with surface of aspis; internal ridges circular in distal ½, longitudinal in sharply narrowed proximal ½; with distinctly porose walls. Sensillus (*ss*) of uniform diameter, subpectinate, bowed, with longest branches on convex side; branches nonbirefringent in polarized light. Interlamellar seta (*in*) inserted close to bothridium; slightly longer than sensillus, finely attenuate and sparsely barbed, probably directed vertically in life. Lamellar seta (*le*) and rostral seta (*ro*) progressively shorter than *in* and inserted closer to meson. Exobothridial setae differing in form; *xs* unusually large, attenuate, length intermediate between *in* and *le*, curving dorsad from insertion anterolaterad of bothridium; *xi* short, straight. Supracoxal seta *el* hollow, incorporated with integument (Fig. 2).

Notogaster (Fig. 1).—Suprapleural band absent[1]. Sclerotization weak or absent in anterolateral region. Anterior extent of sclerotization unclear, but greater medially than laterally, where it ends at level of setae $c_2$ and $c_3$. Setal pair $c_2$ inserted at ends of narrow dark, internal thickening or rib (*ti*) traversing the notogaster. Erectile setae $e_1$, $e_2$ large, extending beyond posterior margin of notogaster when in relaxed position; narrowly rounded distally; with non-birefringent barbs. Setae of pair $e_1$ both inserted on unpaired elongated intercalary sclerite; each seta $e_2$ on a laterally tapering sclerite clearly separated from the central one. Erectile setae $f_1$ and $f_2$ unusually large, dendriform, with thick birefringent branches; tips of branches acute or narrowly rounded. Seta $f_2$ inserted on a simple, trapezoidal intercalary sclerite; $f_1$ sclerite with a distinct straight or slightly curved medial arm. Setae $ps_1$, $ps_2$ broad, foliate; bladelike non-birefringent portion laterally serrated and occupying ⅔ the setal length ($ps_2$, Fig. 3) or entire and occupying ½ the setal length ($ps_1$); birefringent portion basally thick and bifurcated, with paraxial branch short, antiaxial branch long and attenuate. Remaining setae of several types: $c_2$ and $c_3$ relatively short, acute, with 1 or 2 barbs; *cp*, $c_1$, $d_1$, $d_2$, $h_2$ attenuate, with sparse, indistinct barbs; $h_3$ similar, but with barbs distinct; $h_1$ intermediate in size and general appearance between other *h* setae and setae of row *e*; $ps_3$ small, simple, inserted its length away from ventral margin of notogaster at level of posterior margin of genital plate. All but smallest of notogastral setae appear hollow, with very narrow central canal; canal extends into branches of $f_1$, $f_2$. Lyrifissures in form of round or elliptical cupule leading internally to dark, sclerotized tubular canal; *im* located posterolaterad of seta $e_2$ insertion; *ip* posterolaterad of $f_2$ insertion; *ih* located ventrally, anterolaterad of $ps_3$ insertion; *ips* on extreme ventromedial edge of notogaster at folded junction with anogenital region, slightly posteromediad of $ps_3$ insertion; lyrifissue *ia* not observed[2].

Ventral region.—Epimera of pairs I and II well defined, broadly convex; each half-epimere separated from its counterpart by narrow, unsclerotized medial groove. Apodemes $ap_1$ and $ap_2$ distinct. Epimera III and IV both flat; pair III indistinctly separated, fused medially with each other and posteriorly with epimera IV in proximal ⅔; pair IV medially separated by unsclerotized, striate integument. Apodemes $ap_3$, $ap_4$, and *apsj* absent. Epi-

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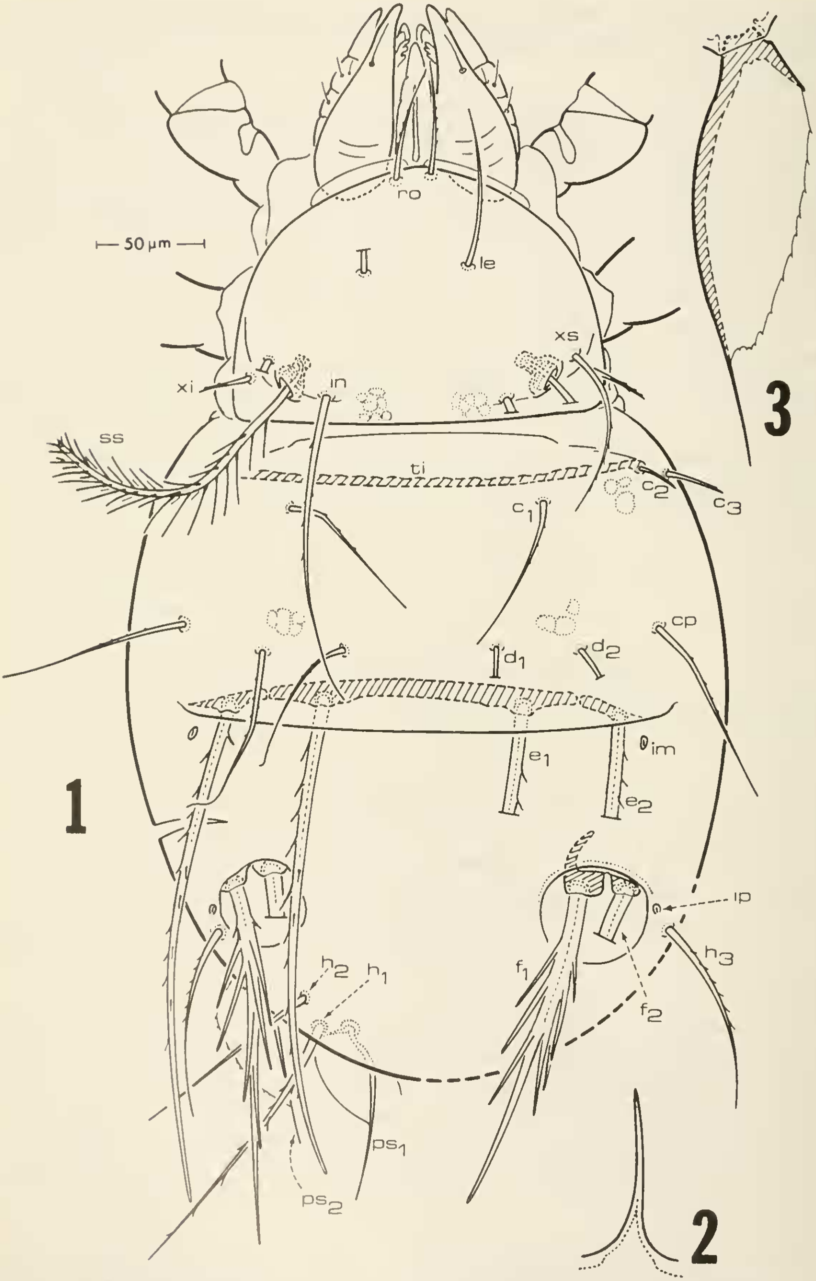
[1] The specimen could not be observed laterally, but there seems to be no lateral break in the sclerotization when viewed dorsoventrally.

[2] It may in fact be present in its usual position posteroventrad of seta $c_3$, but interference of legs III and IV precluded close examination of this area.



Figs. 1–3. *Arborichthonius styosetosus*, holotype female. 1, Dorsal aspect, slightly flattened and broken. 2, Supracoxal seta *el*, dorsal aspect. 3, Seta $ps_2$, dorsal aspect (hatched area is birefringent).

meral setation (I to IV): 3-1-3-4 on left, 3-1-3-5 on right. Genital plates with 3 simple setae in lateral row and 5 (left) or 4 (right) in a medial row. Anal plates immediately adjacent to genital plates and of approximately equal length; each with 2 setae, in anterior ½. Adanal plates fused behind anal plates, posterior separation from notogaster indistinct; 3 pairs of adanal setae. Aggenital region very lightly sclerotized posteriad of single aggenital seta and confluent with adanal plates; area approximately between aggenital seta and epimere IV unsclerotized. Ovipositor short, with distinctly plicate walls; with 9 pairs of setae, 3 pairs on dorsal lobe, 3 on each ventral lobe, and 3 pairs of coronal setae; $\psi_1$ and $\zeta_1$ large and finely attenuate.

Gnathosoma.—Subcapitulum (Fig. 4) with no evidence of secondary articulations. With 4 pairs of subcapitular setae (*a, m, n, h*) of which *a* is clearly thickest and longest. Infrabuccal cleft long; ventral commissure (*Ji*) located slightly posteriad of palpal insertion. Dorsal integument of lateral lips with 4 dark ridges or "chevrons" which appear to radiate from the base of seta *a* in Fig. 4. A pair of sclerotized plates (Fig. 5) present near base of labrum, mediad of seta *m* as seen by transparency, which possess a row of denticles anteriorly and about a dozen longitudinal rows of small rectangular rasplike teeth; laterad, denticles become smaller and longitudinal rows shorter. Rutellum narrow, tridentate. Adoral setae heteromorphic; $or_1$ reduced to small, simple indistinct seta; $or_2$ long, acute, undulating, curving dorsodistally; $or_3$ distally broad, flattened, with a small, but distinct medial notch in the proximal ⅓. Sclerotized pharyngeal cupola (*Co*) present, dorsad of pharynx (*Ph*); without sagittal carina. Chelicera narrow, of the *Hypochthonius* type; each digit with 3 teeth, those of the movable digit concentrated distally. Cheliceral setae subequal; *cha* inserted dorsally, *chb* laterodorsally. Palp (Fig. 6) with setal formula (trochanter to tarsus) of 0-2-1-3-9[3]. Tarsal solenidion $\omega$ medium sized, baculiform, inserted on proximal ½ of tarsus, not reaching distally to tip of segment. Palpal setae smooth or with several small barbs; homologies, indicated in Figs. 6 and 7, with pattern similar to *Hypochthonius* (Grandjean, 1946a). Anteriad of $\omega$ setal alveoli with tear-drop shape, pointed anteriorly. Only large, distal compound seta (fused *ul′*, *ul″*, *sul*) eupathidic; small size precluded determining whether or not individual branches were hollow.

Legs.—Relatively short, simple in form (Figs. 7, 10, 11, 12); lengths (base of trochanter to base of claws) of legs I to IV in proportions 1.3:1.0:1.0:1.2. Basi-telofemur division of leg I indicated by region of non-granulate, unsclerotized integument, broadest antiaxially (Fig. 8), narrowest paraventrally (Fig. 7), with 2 parts of femur joined by region of sclerotized integument extending from dorsal midline midway down paraxial face; setae *d*,

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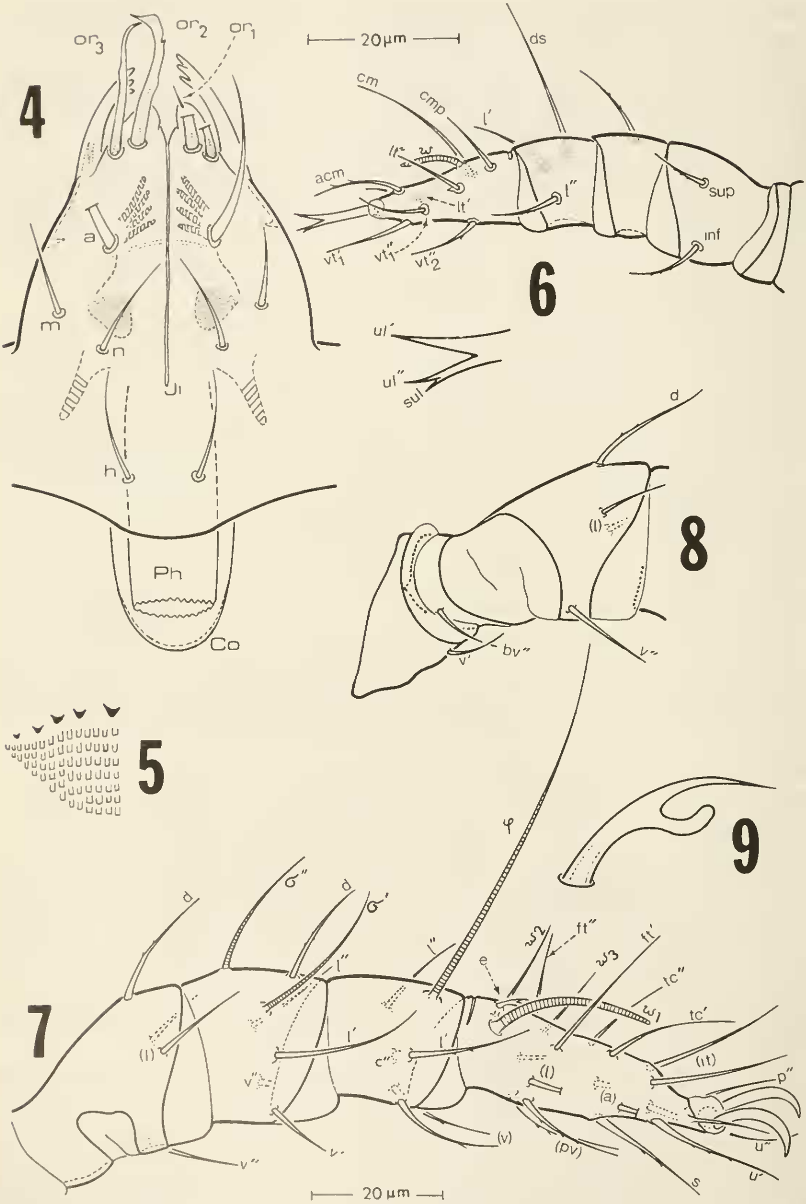
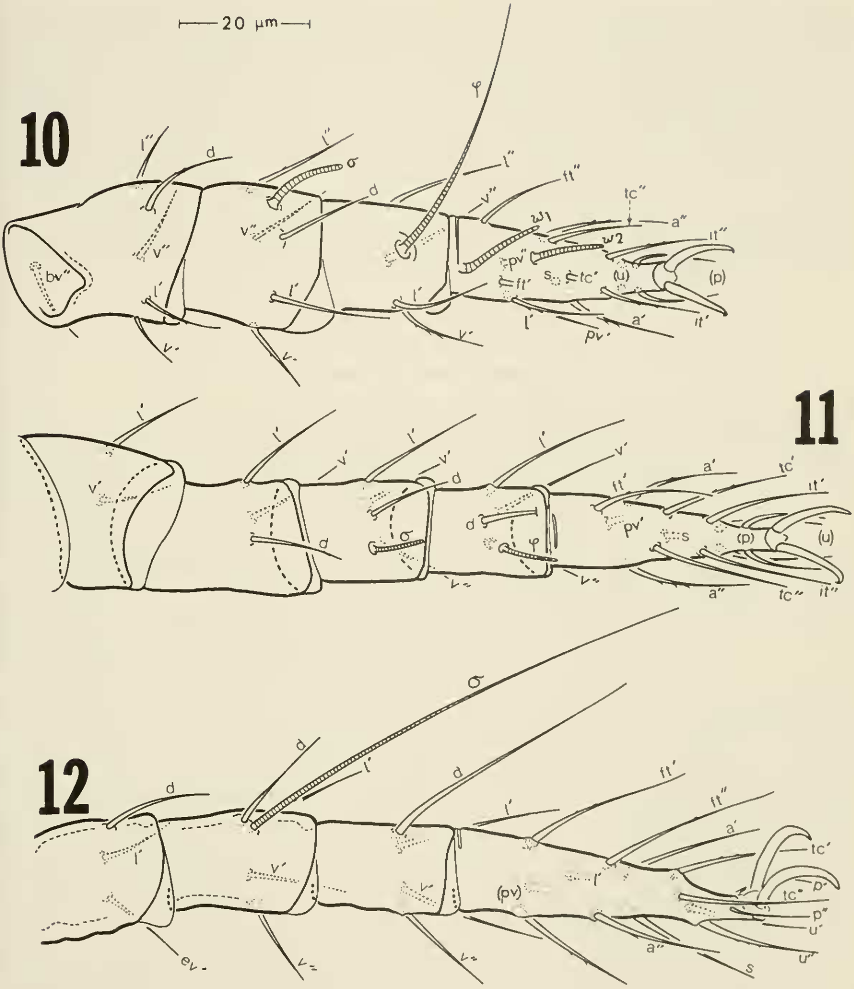
[3] If the branches of the compound eupathid are counted separately, the formula is 0-2-1-3-11.



Figs. 4–9. *Arborichthonius styosetosus*, holotype female. 4, Subcapitulum, ventral aspect. 5, Internal plate of subcapitulum. 6, Palp (same scale as Fig. 4), antiaxial aspect, with enlarged distal eupathid. 7, Leg I (minus trochanter), paraxial aspect. 8, Trochanter and femur I, antiaxial aspect. 9, Famulus.



Figs. 10–12. *Arborichthonius styosetosus*, holotype female. 10, Leg II (minus trochanter), dorsal aspect. 11, Leg III, dorsal aspect. 12, Leg IV (minus trochanter and base of femur), paraxial aspect. Seta *l'* of tarsus absent on other leg IV.

*l'*, *l''*, *v''* on telofemur, *bv''* on basifemur. Ambulacra symmetrically bidactyl; no trace of medial claw or birefringent vestige. Setal formulae (trochanter to tarsus, famulus included) as follows: leg I (1-5-5-5-18); leg II (1-6-5-4-16); leg III (2-3-4-4-13); leg IV (2-3-4-4-13 or 14). Probable setal homologies indicated in illustrations. Many leg setae appear to have thin, inconspicuous central canal, at least near base. Famulus (Fig. 7, *e*, Fig. 9) bifurcate, with ventral branch curved, somewhat spatulate, dorsal branch in form of overhanging bract. Proral setae (*p*) smooth, with large central canal, the only well defined eupathids on tarsus I; subunguinal (*s*, eupathidic in most oribatid mites) similar to other tarsal setae. Solenidial formulae (genu to tarsus) as follows: leg I (2-1-3); leg II (1-1-2); leg III (1-1-0); leg IV (1-0-0). Three are long, tactile: tibial solenidia $\phi$ I and $\phi$ II and genual solenidion $\sigma$ IV. Remaining solenidia baculiform ($\omega_1$I, $\omega_2$II, $\omega_1$II, $\phi$ III, $\sigma$ III, $\sigma$ IV) or piliform ($\omega_2$I, $\omega_3$I, $\sigma'$I, $\sigma''$I). Seta *d* coupled to $\sigma$ on leg IV, in adjacent but separate alveolus. Setae *d* absent on tibiae I and II.

## DISCUSSION

### Unusual Pleisomorphies

1. Independence of leg setae *d*.—*Arborichthonius styosetosus* is one of the few Enarthronota which do not completely exhibit the derived close association, or coupling, of genual and tibial solenidia (on legs where they exist) with normal setae (usually *d*) of the respective segments. Some terminology helpful in discussing such couplings can be defined as follows: 1) Imperfect coupling occurs when the seta and solenidion are inserted in separate, but adjacent alveoli; 2) perfect, or normal coupling occurs when both are inserted in a common alveolus, although the seta may be small and regressive, or even fused to the solenidion; 3) hyperperfect coupling occurs when the normal seta has regressed to the point of dissappearing, leaving only the solendion, which is typically very large and tactile in form. Hyperperfect coupling may be the culmination of an ontogenetic trend, as seen in certain brachypyline oribatid mites (such as *Epidamaeus*) where *d* becomes gradually smaller in the immature instars and is absent in the adult instar. It also appears to culminate a similar phylogenetic trend, with the result that seta *d* may be absent in all instars, as is common in poronotic Brachypylina. Grandjean (1946b) has called these two apomorphies the *Scutovertex* stage and *Galumna* stage, respectively. It is clear, however, that we are dealing with grades of evolutionary development, which like many regressive apomorphic states, have been reached independently in multiple lineages.

*Arborichthonius styosetosus* exhibits several grades of coupling. There is none on genua I–III and tibia III, where seta *d* and the respective baculiform solenidion are independent and distant. Imperfect coupling is found on genu IV, where solenidion $\sigma$ is tactile. Hyperperfect coupling is found on tibiae I and II; whether or not this develops during ontogeny is not known. The absence of coupling on one or more genua or tibiae (where solenidia are present) is known in only three other enarthronote species; these comprise the superfamily Pterochthonioidea (Grandjean, 1948, 1950; Travé, 1967). *Pterochthonius* exhibits perfect and hyperperfect coupling, as well as independence of seta *d*, whereas all setae *d* are independent in *Atopochthonius* and *Phyllochthonius*. Among non-enarthronote oribatid mites independent setae *d* (on genua and tibiae with solenidia) are found only in the Palaeosomata and the genera *Eulohmannia* and *Elliptochthonius*, where coupling is totally absent, and *Nehypochthonius*, *Parhypochthonius*, *Gehypochthonius*, and *Perlohmannia*, where coupling is only found on certain legs.

Although the ultrastructural proof is not yet available, it is reasonable to suggest that the eventual result of the development of coupling and ontogenetic or phylogenetic loss of the normal seta is a gradual takeover of dorsal mechanoreceptive function by the large, flagellate, tactile, chemoreceptive solenidion. Ancestrally, chemoreceptive and dorsal mechanoreceptive functions were presumably performed by the separate structures. From a mechanoreception standpoint, the advantage of coupling, particularly the hyperperfect type, may be that solenidia, which are hollow (and presumably less dense than normal setae) and elastic, may be less prone to breakage than similarly sized flagellate normal setae, which are solid and more brittle.

2. Solenidial formulae.—Also rather primitive is the rich complement of solenidia; next to *Atopochthonius* and *Phyllochthonius*, is the least regressive known in the Enarthronota. Among all known Oribatei (Grandjean, 1964) the specific formula of *Arborichthonius* is unique.

3. Rostral tectum.—*Arborichthonius* is one of the few enarthronote genera to retain the ancestral astegasime condition, whereby the rostral tectum is poorly developed, not fully covering the retracted mouthparts from above. Some Brachychthoniidae, such as *Liochthonius* are astegasime (Grandjean, 1963), as is the haplochthoniid genus *Amnemochthonius* (Grandjean, 1948). Both genera contain very small and incompletely sclerotized species which are regressive in many characters; whether or not the astegasime condition is also a result of regressive loss of rostral sclerotization is not clear in these groups. *Arborichthonius* maintains astegasimy despite light but relatively uniform general sclerotization.

4. Divided femur I.—This is one of the most interesting character states exhibited by *Arborichthonius*. Within the Oribatei, divided femora were known only in the Palaeosomata and are considered ancestral to the typical single femur formed by the integration of these two segments (Grandjean, 1954b). *Arborichthonius* exhibits a partially divided femur (Figs. 7, 8); the separation is incomplete in the paradorsal region and appears, in effect, to form a poorly defined hinge. Is this subdivision ancestral or secondarily derived by localized desclerotization? There is little evidence to support either conclusion and what does exist is somewhat contradictory. The central placement of the division and femoral chaetotaxy support the former conclusion; seta *bv″* is a basifemoral seta in the Palaeosomata, *d*, *l′*, *l″* and

$v''$ are telofemoral setae (Grandjean, 1954b). Secondary desclerotization might have produced a deviant pattern of setal distribution between the two parts. Also, the fact that the division is on the first leg and not the others is consistent with Grandjean's view on retardation of character appearance; in the Palaeosomata leg I develops the division earlier than the other legs and would be the last to lose this character if retardation was occurring in phylogenetic time. On the other hand, the presence of smooth articulating integument, in contrast to the granulate arthrodial integument between other leg segments, is consistent with a hypothesis of secondary desclerotization.

## Unusual Apomorphies

1. Notogastral setae.—Like certain other Enarthronota, *Arborichthonius* has hypertrophied notogastral setae which the mite can raise and lower. The evidence for this is in the nature of their insertions. In sclerotized Enarthronota, erectile setae always insert on an intercalary sclerite which is bordered anteriorly and posteriorly by unsclerotized integument. In previously described species these intercalary sclerites are associated with one of the transverse notogastral scissures characteristic of the Enarthronota, such that when the notogastral plates immediately in front of and behind the scissure are pulled apart, presumably by hysterosomal distension but possibly by bending the hysterosoma ventrally, the unsclerotized connective integument is stretched and the associated setae erected (Grandjean, 1931). Grandjean (1946c) has called this kind of scissure "type S." *Atopochthonius, Phyllochthonius* and certain Palaeosomata have erectile setae which apparently function in a similar way, except that there are no articulating notogastral plates and erection appears to be simply a result of general stretching of gastronotic integument by hysterosomal distension (Grandjean, 1948). *Arborichthonius* exhibits a type S scissure bearing erectile setae $e_1$ and $e_2$. Although the three dimensional body shape of the *Arborichthonius styosetosus* holotype is difficult to determine, due to flattening on the microscope slide, the fact that the intercalary sclerite bearing the setae of pair $e_1$ is not divided is evidence that the mite is rather flat in life. Grandjean (1948) has noted that separation of intercalary sclerites, such as is found between all other such sclerites of *Arborichthonius*, is necessary in convex mites in order to avoid cuticular distortion when setae are erected.

Unlike other known sclerotized enarthronote mites, *Arborichthonius* has erectile setae which are not associated with a type S scissure. Setae $f_1$ and $f_2$ are inserted in paired circular regions of unsclerotized integument which are concave when setae are in their resting (horizontal) position. The erectile nature is certain because of the adjacent, but independent intercalary sclerites on which they insert. Hysterosomal distension presumably causes the unsclerotized integument to bulge outward, erecting the four setae.

Foliose setae $ps_1$ and $ps_2$, while not erectile, are unlike any known in other oribatid mites. Combined with the large dendriform setae of row *f*, they give the posterior region a general appearance more characteristic of certain Scutacaridae (Prostigmata) than an oribatid mite.

2. Pharyngeal cupola.—The most complex, specialized pharyngeal structure known in oribatid mites is found in the enarthronote superfamily Cosmochthonioidea and the derivative Protoplophoridae (Grandjean, 1946c, 1954a, 1962). Included in this aspiratory apparatus is a thin, ventrally concave sclerotized internal plate on which the dilator muscles of the pharynx originate. Because of the association with pharyngeal musculature, this plate, or cupola, appears to be a derivative of the epistome of other arachnid groups. *Arborichthonius, Atopochthonius* and *Phyllochthonius*, while lacking most of the pharyngeal specializations of cosmochthonioid mites, do exhibit a thin cupola dorsad of the pharynx, although it is not as well developed as in the latter group.

3. Adoral setae.—*Arborichthonius* belongs to a small group of Enarthronota with unusual adoral setae; this group also includes *Hypochthonius, Hypochthoniella, Atopochthonius, Phyllochthonius, Mesoplophora,* and *Archoplophora*. Typically, seta $or_1$ is highly reduced or vestigial; $or_2$ is large, flattened, spatulate, or otherwise specialized, but always exhibits an unusual medial notch somewhere near its midpoint; $or_3$ is also large, but attenuate except in the later two genera. This combination of adoral modifications appears to be a synapomorphy.

4. Bidactyly.—Few oribatid mites are symmetrically bidactyl. Except for *Gehypochthonius rhadamanthus* Jacot and the enarthronote genera *Arborichthonius, Atopochthonius,* and *Phyllochthonius*, the only known bidactyl oribatid mites are those in which one of the lateral claws has been lost (Grandjean, 1939). These four taxa have well developed lateral claws as adults but not even a vestige of a central claw. One can suggest that this is an evolutionary grade a step beyond that of *Acaronychus, Eulohmannia, Nehypochthonius, Elliptochthonius, Parhypochthonius,* and *Gehypochthonius xarifae* Strenzke in which the central claw is highly reduced in size. The presence of symmetrical bidactyly in the Enarthronota as well as both bidactyly and centrally regressive tridactyly in the genus *Gehypochthonius*, suggests that symmetrical bidactyly has appeared in more than one lineage.

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